86th Congress, 1st Session - - - - House Document No. 71

U.S. AERONAUTICS AND SPACE ACTIVITIES, JANUARY 1 TO DECEMBER 31, 1958

MESSAGE

FROM

THE PRESIDENT OF THE UNITED STATES

TRANSMITTING

THE FIRST ANNUAL REPORT ON THE NATION'S ACTIVITIES AND ACCOMPLISHMENTS IN THE AERONAUTICS AND SPACE FIELDS, PURSUANT TO SECTION 206(b) OF THE NATIONAL AERONAUTICS AND SPACE ACT OF 1958

FEBRUARY 2, 1959.—Referred to the Committee on Science and Astronautics and ordered to be printed

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UNITED STATES
GOVERNMENT PRINTING OFFICE
34011 WASHINGTON : 1959

LETTER OF TRANSMITTAL

To the Congress of the United States:

Transmitted herewith, pursuant to section 206(b) of the National Aeronautics and Space Act of 1958, is the first annual report on the Nation's activities and accomplishments in the aeronautics and space fields. This first report covers the year 1958.

The report provides an impressive accumulation of evidence as to the scope and impetus of our aeronautical and space efforts. Equally impressive is the report's description of the variety of fields being explored through the ingenuity of American scientists, engineers, and technicians.

The report makes clear that the Nation has the knowledge, the skill and the will to move ahead swiftly and surely in these rapidly developing areas of technology. Our national capability in this regard has been considerably enhanced by the creation and organization of the National Aeronautics and Space Administration.

The report sets forth a record of solid achievement in a most intricate and exacting enterprise. In this record the Nation can take great pride.

DWIGHT D. EISENHOWER.

THE WHITE HOUSE, *February 2, 1959.*

U.S. AERONAUTICS AND SPACE ACTIVITIES, JANUARY 1 TO DECEMBER 31, 1958

Year One of the Space Age

SUMMARY

The United States entered the age of space exploration on January 31, 1958.

At 11:12 p.m. on that date, the U.S. experimental satellite Explorer I boosted into space by an Army Jupiter-C rocket, swung into an earth orbit with an apogee of some 1,600 miles and a perigee of about 230 miles. This was 7 minutes after lift-off from a launching pad at Cape Canaveral, Fla. Explorer I, first U.S. scientific instrument to reach the fringes of deep space, still circles the globe 12.8 times a day.

The past year has seen notable progress in the space effort of the United States. Five U.S. satellites have gone into orbit. Two space probes, one launched in October and the other in December, traveled about 71,300 and 63,580 statute miles, respectively, before Earth's gravity reclaimed them.

With one exception—the Atlas satellite communications experiment in December—these accomplishments were part of the U.S. contribution to the International Geophysical Year (IGY).

Satellites and probes alike were instrumented. Their telemetry reported a wealth of new data about the distribution of matter and of the magnetic fields and radiation encountered in space, information vital to the future of space flight—manned and unmanned. From the continuing scientific program will come the data on which to base future long-range weather forecasting, telecommunications, and many scientific, military, and industrial applications. Out of research and development projects for space devices are being evolved special fuels, materials, components and techniques that will find other uses in the Nation's economy.

A key event of the year was the passage of legislation, formulated by Congress and the President, that provided for organization under a new agency, the National Aeronautics and Space Administration (NASA), of all Government aeronautics and space programs except—

> activities peculiar to or primarily associated with development of weapons systems, military operations, or the defense of the United States.

The National Aeronautics and Space Act also established a council to advise the President on all phases of the national aeronautical and space effort. Within the Department of Defense, the Advanced Research Projects Agency (ARPA) was established to direct military space activities. A Civilian-Military Liaison Committee was created by the National Aeronautics and Space Act as one of the means of coordinating NASA and Department of Defense space and aeronautics work.

NASA is expanding research and development programs that were already in progress. It is planning and undertaking new programs aimed at exploring our solar system: first by unmanned, then by manned deep-space vehicles. Typical examples follow:

With ARPA support, NASA has management and technical direction of Project Mercury, the manned satellite program. Preliminary specifications for a space capsule suitable for manned satellite flight were issued by NASA in November and a contract for its development was awarded early in 1959.

On October 15, the X-15, a rocket-propelled research airplane designed to take a human being into nearby space under some of the conditions to be encountered in actual interplanetary flight, was officially unveiled to the public. The X-15 is scheduled for tests early in 1959. A round-trip venture to the outer reaches of the Earth's atmospheric screen will be attempted later in this aircraft.

In mid-December, NASA designated an industrial source to design and develop a single-chamber rocket engine that will have a thrust of 1.5 million pounds. Development of a clustered booster, designed to deliver 1.5 million pounds of thrust, was begun in August under ARPA direction.

As manmade devices, one after another, have reconnoitered the frontiers of space, there is realization that the human race has begun its greatest, most daring adventure. The benefits that will come as man's peaceful conquest of space proceeds, should be shared with the world.

The groundwork for cooperation and knowledge-sharing has been laid by the 66 nations participating in the International Geophysical Year. In the spirit of the IGY, it is the policy of the United States to make available to the world the scientific results of its nonmilitary research into problems of flight within and beyond the Earth's atmosphere.

During the year the United States had a leading role in United Nations efforts to bring about international cooperation in peaceful activities. A resolution to further this ideal, introduced by this country, November 18, in the U.N. General Assembly, was overwhelmingly approved on December 13, 1958.

The succession of satellites, missiles, and experimental space probes launched by the United States in 1958—sometimes with success, sometimes not—was the outcome of planning carried on for several years. Since the end of World War II, the United States has engaged in various types of space-related research out of which some of today's important programs have grown. The Army, the Navy, the Air Force, and NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), and other agencies have participated in studies and experiments with rockets, rocket-powered aircraft, special fuels, and novel methods of propulsion beyond the Earth's atmosphere. Basic research support programs of the National Science Foundation have contributed substantially to advances in the underlying science upon which our progress in space technology depends. The science of space medicine, whose object is to prepare man for cosmic flight, has been established for a decade or more.

This work went on at isolated test facilities, little known to the public, and in research laboratories scattered over the land. The components for the drive into space were there—vehicles for different purposes, instruments of various kinds, and knowledge accumulated about the environment high above our ocean of air. Some of the parts had been put together into specific programs, such as the Vanguard project, but the assortment of detached plans and unassimilated ideas had yet to be assembled.

A fundamental achievement of 1958—first full year of the space age—was in placing the U.S. effort under coordinated direction. At the beginning of the year the United States had yet to launch a single true space vehicle, and the various activities working toward this objective were being conducted almost entirely independently of one another. At the year's end our achievements in space research were many and substantial, while the arrangements established to coordinate them in the future were in operation.

Main events and programs of the first U.S. space year follow:

LAUNCHING FOR THE INTERNATIONAL GEOPHYSICAL YEAR

First steps

On July 29, 1955, the United States announced it would launch earth satellites during the 18-month International Geophysical Year which ended formally on December 31, 1958. After proposals from the three military services had been studied, the Government approved a Naval Research Laboratory plan for constructing a three-stage rocket capable of placing a spherical, 21½-pound, instrumented satellite in orbit. The program, which came to be known as Project Vanguard, also called for establishing a worldwide minitrack network to track space vehicles by radio.

The Vanguard rocket is tall (72 feet) and slim (45 inches in diameter at the base) with a gross takeoff weight of 22,600 pounds. It consists of liquid propellant first and second stages and a solid propellant third stage. The second stage contains the rocket's guidance and control system.

Three successive test firings of Vanguard's first and third stages were successful. However, the three stages in combination failed when test-fired for the first time on December 6, 1957.

Satellites

On January 31, 1958, the Army Jupiter-C—an elongated Redstone, topped by two stages composed of scaled-down Sergeant rockets in clusters, with a single rocket as fourth stage—was fired successfully from the Atlantic Missile Range, Cape Canaveral, Fla. Explorer I, as its scientific payload was christened, is a bullet-shaped, steel cylinder 80 inches long and 6 inches in diameter. It weighs 30.8 pounds, 11 pounds of which are scientific instruments, including a Geiger-Mueller cosmic ray counting tube, 2 micrometeor detector experiments, and 4 gages to measure temperature inside the satellite and on its outer skin.

Explorer I is credited with what is probably the most important satellite discovery of the IGY, the Great Radiation Belt, identified by James A. Van Allen, head of the State University of Iowa physics department.

Great Radiation Belt.—Preliminary examination of data from Explorer I (and from later Explorer Satellites III and IV, as well as from the Air Force Pioneer I and the Army Pioneer III space probes) reveals the existence of a pair of bands or clouds of charged particles, protons or electrons, or both.

Apparently the first radiation belt extends to 3,400 miles above the surface of the Earth. The second belt, about 4,000 miles thick, extends outward some 8,000 to 12,000 miles. The particles composing the pair of belts reach the first peak intensity at an altitude of approximately 2,400 miles and peak again at 10,000 miles.

When these particles, streaming from the sun or other sources deep in space, reach the Earth's magnetic field, some are deflected, a few filter through and are absorbed in the atmosphere, but a great many oscillate in spiral paths along the magnetic field's lines of force.

According to Van Allen, there is negligible radiation danger to man below the first belt—and between the first and the second belts. Similarly, the radiation tapers off to safe levels after reaching its second peak of intensity at 10,000 miles.

In each band, electron bombardment at peak is equivalent to about 10 roentgens per hour and that for protons is about 100 roentgens per hour. Man's permissible radiation dosage per year is only five roentgens, so it can readily be seen that effective, lightweight shielding must be devised before human beings can travel safely within these bands of radiation.

Van Allen concludes that the radiation belts do not extend over the Arctic and Antarctic regions; they appear roughly to follow the lines of force of the Earth's magnetic field which loop outward and converge about radiation-free voids at the North and South magnetic poles. If it proves necessary to shun these belts entirely, an escape into space via the polar regions may be feasible.

Many more experiments will be undertaken in 1959 to determine the nature of this radiation and to gain more information about its intensity and range.

U.S. satellites, lunar probes, and space probes, 1958

Name	Lifetime	Dimensions	Shape	Weight (pounds)	Type	Perigee (miles)	Apogee (miles)
Explorer I	Jan. 31, 1957 (3 to 5 years)	80 inches long; 6 inches in diameter	Cylinder	30.8	Satellite	224	1,573
Vanguard (test vehicle 3 backup)	Feb. 5, 1958 (0)	6 inches in diameter	Sphere	3.4	do	0	0
Explorer II	Mar. 5, 1958 (0)	80 inches long; 6 inches in diameter	Cylinder	18.8	do	0	0
Vanguard I	Mar. 17, 1958 (200 years)	$6\frac{4}{10}$ inches in diameter	Sphere	3.25	do	409	2,453
Explorer III	Mar. 26 to June 27-29, 1958	80 inches long; 6 inches in diameter	Cylinder	31.0	do	118	1,740
Vanguard (test vehicle 5)	Apr. 28, 1958 (0)	20 inches in diameter	Sphere	21.5	do	0	0
Vanguard (satellite-launching vehicle I)	May 27, 1958 (0)	do	do	21.5	do	0	0
Vanguard (satellite-launching vehicle II)	June 26, 1958 (0)	do	do	21.5	do	0	0
Explorer IV	July 26, 1958 (still in orbit January 1959)	80 inches long; 6 inches in diameter	Cylinder	37.10	do	157	1,380
Thor Able I (no name)	Aug. 17, 1958 (0)	30 inches long; 29 inches in diameter	Toroidal	[1] 85	Lunar probe	(Altitude: 40,000 to 70,000 feet)	
Explorer V	Aug. 24, 1958	80 inches long; 6 inches in diameter	Cylinder	25.8	Satellite	0	0
Vanguard (SLV-III)	Sept. 26, 1958 (0)	20 inches in diameter	Sphere	21.5	do	0	0
Pioneer I	Oct. 11-12, 1958 (42 hours and 4 minutes)	30 inches long; 29 inches in diameter	Toroidal	[1] 85	Lunar probe	(Altitude: 71,300 miles)	
Beacon	Oct. 23, 1958 (0)	12 feet in diameter; inflatable sphere	Sphere	9.26	Satellite	0	0
Pioneer II	Nov. 8, 1958 (0)	30 inches long; 29 inches in diameter	Biconical	[1] 85	Lunar probe	(Altitude: 1,000 miles)	
Pioneer III	Dec. 6-7, 1958 (38 hours and 6 minutes)	23 inches long; 10 inches in diameter	Conical	12.95	Space probe	(Altitude: 63,580 miles)	
Project Score (Atlas)	Dec. 18, 1958 (to about Jan. 21, 1959)	85 feet long; 10 feet in diameter	Cylindrical	[2] 8,700	Satellite	114.5	928

[1] Including 4th stage.

[2] In orbit.

Explorer II, launched on March 5 under ARPA direction, failed to achieve orbit when the fourth stage did not ignite.

Explorers III and IV, fired on May 15 and July 26 under the direction of ARPA with the Army as executive agent, yielded valuable data on the radiation belts discovered by Explorer I as well as data on micrometeoric impacts (density of cosmic dust) and on internal and external temperatures of the satellite.

According to William H. Pickering, Director of the NASA-California Institute of Technology Jet Propulsion Laboratory:

> We have demonstrated an ability to obtain maximum information from our relatively small payloads by virtue of miniaturization techniques in electronics. And we also have shown a flexibility in our program by adjusting missions to fully exploit discoveries made by earlier satellites, such as the development of the radiation package in Explorer IV to investigate the radiation phenomenon found by Explorers I and III.

Van Allen summed up the scientific significance of the foregoing launchings this way:

> We scientists are sometimes asked, "What good is all this knowledge?" The data we are receiving from Explorer is, to be sure, limited. Cosmic rays, meteoric dust, and temperatures of objects in space sound like remote matters in the daily lives of people on Earth. But it is only by building our knowledge, fact by fact, that we will lay the groundwork for the more practical discoveries that lie ahead.
>
> Future weather patrol satellites can be expected to provide far-reaching benefits. Besides improving day-to-day forecasting, meteorologists might be able to predict droughts and rainy spells a year or more in advance. The value of such information to farmers is beyond estimation. Hurricanes and tornadoes could be spotted at birth and their deadly paths predicted.

On March 17, Vanguard I was fired from Cape Canaveral. Everything functioned smoothly. Into orbit went a 3¼-pound test satellite, which, it is estimated, will continue circling in space for hundreds of years.

The satellite's radio, equipped with solar batteries, is still transmitting as it orbits the world every 134 minutes, soaring from a perigee of 409 miles to an apogee of 2,453 miles.

The Army Map Service has been making electronic observations of the satellite from several Pacific islands to pinpoint the islands' locations more exactly. The satellite is also being used for more exact determination of the Earth's shape.

Three other Vanguard firings in 1958 failed to place satellites into orbit, although they did achieve other test objectives. During the year, ARPA authorized three space probes by the Air Force, two by the Army. These IGY projects were placed under the aegis of NASA on October 1, along with Project Vanguard and a number of other programs which had been under ARPA direction.

Thrusts into deep space

The mission of the first space probe, August 17, was to place an 85-pound payload—including an electronic scanning device to produce crude images of the far side of the Moon—in the vicinity of the Moon, more than 220,000 miles from Earth. The Thor-Able-I test vehicle consisted of a standard Thor for the first stage with a liquid-fuel, modified Vanguard second stage, a solid propellent third stage, and a solid propellent terminal or retrorocket as its fourth stage.

The first attempt ended in failure when the rocket exploded 77 seconds after liftoff.

The next attempt, with a payload of more advanced instrumentation, had essentially the same mission, and was deemed a qualified success despite the fact that it did not reach the Moon. It traveled 71,300 miles into space, about 30 times farther than any man-made device had gone until that time. After a 43-hour flight, the 82.71-pound probe reentered the Earth's atmosphere and burned.

An error of 3.5° in the first stage of the trajectory prevented the rocket from attaining the velocity needed to reach the vicinity of the Moon.

On November 8, Pioneer II, the third attempt—under NASA, management with the Air Force as agent—ranged only 7,500 miles after its third stage failed to ignite.

Pioneer III, NASA with the Army as agent, was considered a qualified success. On December 6, Juno II, a modified Jupiter with several solid-fuel upper stages, launched a 12.95-pound instrument package into space. The fuel in the first stage cut off 3.7 seconds too soon, robbing the vehicle of its necessary escape speed. As a result, the probe failed to reach the vicinity of the Moon and pass on to a possible orbit around the Sun. It did, however, fly 63,580 miles and its telemetered measurements yielded valuable radiation data, as indicated earlier.

Pioneer III's temperature-control method, essentially the same as that employed in the Explorer series, was also a success. It consisted of coating the payload's exterior with stripes of black and white zirconium oxide to control the heat input and output. Only by stabilizing the interior temperature between certain limits can scientists be certain that the temperature-sensitive electronic components will function properly.

Another NASA space probe, with the Army as agent, is scheduled for early 1959.

Inflatable satellites

In late October, NASA, with the Army as executive agent, attempted to place in orbit an inflatable satellite, 12 feet in diameter and made of highly reflective aluminum foil and microthin plastic film. The experiment was designed to produce data on atmospheric density at altitudes up to 400 miles. The second stage of the Jupiter C launching vehicle did not ignite and the experiment was not completed.

NASA, which designed and developed the inflatable sphere, plans to launch a 100-foot inflatable satellite and possibly another 12-foot inflatable satellite.

U.S. contributions to the IGY space program also included some 200 upper-atmosphere rocket soundings and a number of balloon ascents, as well as many other geophysical investigations.

PROJECT SCORE

On December 18, ARPA, with the Air Force as agent, fired an Atlas intercontinental ballistic missile into orbit. The 150-pound payload attached to its 4.5-ton final rocket stage contained instrumentation that included radio equipment, tape recorder and transmitter. Titled "Project Score," for signal communications orbital relay experiment, it was a dramatic demonstration of the potentialities of communications satellites.

The missile (85 feet long, 10 feet in diameter) lifted off within 2 minutes after scheduled launch time. Its two powerful first-stage engines (approximately 150,000 pounds thrust each) dropped after burnout, leaving the central sustainer engine to carry on to the end of the powered flight phase.

At this point the rocket's guidance system injected it into orbit, placing it in proper horizontal position precisely on time schedule.

The orbit of the 8,750-pound last stage with its 150-pound payload was at apogee about 625 miles—at perigee about 118 miles. Orbital speed was 17,000 m.p.h., or 1 circuit of the Earth every 100 minutes.

The satellite's communication equipment—modified standard items, for the most part—consisted principally of twin packages of radio transmitting, recording, and receiving apparatus, each weighing 35 pounds. Other components included a battery, a voltage converter, a radio beacon, and a control unit.

Recorded on tape at liftoff was a goodwill message from the President which was transmitted the following day. It was the first time a human voice had been beamed from outer space. The message was as follows:

> This is the President of the United States speaking. Through the marvels of scientific advance, my voice is coming to you from a satellite circling in outer space.
>
> My message is a simple one. Through this unique means I convey to you and to all mankind America's wish for peace on earth and good will toward men everywhere.

Later, the satellite accepted and relayed messages from ground stations in Texas, Arizona, and Georgia.

PREPARING FOR SPACE

Basic recommendations and organization

The need for central direction and coordination of all phases of the space effort became apparent late in 1957. U.S. requirements in space science and technology were studied by the President's Science Advisory Committee, of which James R. Killian is Chairman. This Committee and the President's Advisory Committee on Government Organization recommended that a civilian agency be formed to direct nonmilitary space activities. The President recommended formation of such an agency in his special message to Congress on April 2.

Department of Defense-ARPA.—Earlier a transitional organization was formed, February 7, 1958, when military space projects were unified under the Advanced Research Projects Agency by direction of the Secretary of Defense. In addition, ARPA administered all other U.S. space programs from February to October when NASA assumed responsibility for nonmilitary programs.

NASA established.—The National Aeronautics and Space Administration was created as an executive agency of the Government. The legislation directed that—

> the general welfare and security of the United States require that adequate provisions be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the re-

sponsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President * * *

In the President's special message to Congress, April 2, in which establishment of NASA was recommended, it had been emphasized that—

aeronautical and space science activities sponsored by the United States be conducted under the direction of a civilian agency, except for those projects primarily associated with military requirements. I have reached this conclusion because space exploration holds promise of adding importantly to our knowledge of the Earth, the solar system, and the universe, and because it is of great importance to have the fullest cooperation of the scientific community at home and abroad in moving forward in the fields of space science and technology. Moreover, a civilian setting for the administration of space function will emphasize the concern of our Nation that outer space be devoted to peaceful and scientific purposes.

It is the role of NASA to initiate and support projects to—

Expand human knowledge of the phenomena in the atmosphere and in space;

Improve the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

Develop and operate space vehicles for a variety of purposes;

Study potential benefits to be gained for mankind through space activities;

Preserve the role of the United States as a leader in aeronautical and space activities for peaceful purposes;

Interchange information between the civilian and military agencies to assure maximum effectiveness of discoveries for all purposes;

Cooperate with other nations in such activities and in peaceful application of the results; and,

Seek the most effective utilization of scientific and engineering resources of the United States in achieving these goals.

The President appointed T. Keith Glennan, president-on-leave of Case Institute of Technology, Cleveland, Ohio, as NASA's first Administrator. Hugh L. Dryden, NACA's Director for 9 years, was named Deputy Administrator.

Aeronautics and Space Council.—The nine-member National Aeronautics and Space Council was established by the act to advise the President on "all significant aeronautical and space activities." The act stipulates that the President shall preside over meetings of the Council. Statutory members of the Council are: The Secretary of State (John Foster Dulles); the Secretary of Defense (Neil H. McElroy); the Chairman of the Atomic Energy Commission (John A. McCone); and the Administrator of the National Aeronautics and Space Administration (T. Keith Glennan). In addition, the President appointed to the Council: Alan T. Waterman, Director, National Science Foundation, and Detley W. Bronk, President, National Academy of Sciences. To recess appointments, the President named: James H. Doolittle, vice president, Shell Oil Co., and William A. M. Burden, general partner, William A. M. Burden & Co., Investment Bankers, New York City. Organized in October, the Council met three times during 1958.

NASA begins operating.—NASA became effectively operative on October 1, at which time it absorbed the personnel and facilities of the 43-year-old National Advisory Committee for Aeronautics, consisting of NACA's nearly 8,000 scientists, engineers, and technical and administrative personnel in a Washington, D.C., headquarters and 5 field laboratories. The laboratories are: Langley Research Center, Langley Field, Va.; Ames Research Center, Moffett Field, Calif.; Lewis Research Center, Cleveland, Ohio; the Pilotless Aircraft Research Station, Wallops Island, Va.; and the High Speed Flight Station, Edwards, Calif.

NASA also has a new space projects center under construction at Beltsville, Md., just outside of Washington, D.C. It should be ready for occupancy early in 1960.

In early October, Administrator Glennan announced that NASA's organizational structure would include space flight development on the one hand, and aeronautical and space research on the other.

Before passage of the Space Act, the President had called upon the Department of Defense and NACA to carry out a joint review of aeronautical and space projects which should, appropriately, be placed under direction of the new agency. These programs, summarized earlier in this report, were transferred to NASA on October 1:

Project Vanguard, with more than 160 scientists and technologists of the Naval Research Laboratory, Washington, D.C.

Five space probes which were under the direction of ARPA.

Three satellite projects: 12-foot and 100-foot-diameter inflatable spheres and a cosmic ray experiment.

A number of ARPA and Air Force engine development research programs, including their work on nuclear and fluorine rocket engines and study and development of a 1.5 million-pound thrust single-chamber rocket engine.

On December 3, NASA entered into an agreement with the Army whereby the Ballistic Missile Agency (ABMA), Huntsville, Ala., will carry out certain NASA projects. At the same time, the President issued Executive Order 10793, transferring the functions and facilities of the Jet Propulsion Laboratory, Pasadena, Calif., from the Department of the Army to NASA. The order also transferred funds from Defense appropriations to NASA for execution of JPL projects.

In signing the order the President said:

> This decision is necessary in the national interest. It prevents unnecessary duplication and effects economies in space research and development. This development will enhance close cooperation between the National Aeronautics and Space Administration and the Department of Defense to the end that the peaceful use of space will redound to the benefit of all mankind.
>
> I am gratified that the Department of Defense and National Aeronautics and Space Administration have reached agreements under which the National Aeronautics and Space Administration will use the unique capabilities of the Army Ordnance Missile Command, including the Army Ballistic Missile Agency, on a fully cooperative basis.

Research and development on space

Before any space device is ready for launching, complex preparations are necessary, ranging from investigation of theoretical concepts to the design and construction of the operating satellite or probe. These preparations often require years of effort, each step carefully executed from the research through the development stages. It is not always possible, however, to draw a precise line of demarcation between research and development.

In the space program, research is essentially exploration of the basic laws of the universe to discover new scientific information, while development makes use of existing knowledge to design, construct and test experimental devices or equipment used in support of space activities. Frequently discoveries made in the development and operational testing stages are fed back into fundamental research, setting off new cycles of basic investigation. Space research and development is thus an open-end process, with one step into the unknown leading to another, sometimes to end in blind alleys, sometimes to break through into undreamed-of areas of knowledge. It should be remembered that sound research and development is time-consuming, that results must be checked and rechecked painstakingly before they can be applied.

Research and development for space cuts across and draws upon practically every field of science and engineering. For example, on December 13, 1958, when the Army's specially conditioned squirrel monkey Gordo was rocketed some 300 miles above the Earth's surface in a miniature space capsule, there was scarcely a human skill or area of knowledge that somewhere along the line had not contributed to the undertaking.

NASA-Department of Defense Coordination.—NASA and the Department of Defense are taking care to avoid duplication. One duty of the Civilian-Military Liaison Committee is to serve as an information clearing house to prevent duplicate work, where possible. Moreover, the Secretary of Defense and the Administrator of NASA are members of the National Aeronautics and Space Council.

National Science Foundation support.—Among other arrangements for strengthening the national space program is that between the National Science Foundation and NASA. Under law and Executive order, the Foundation is responsible for the support through grants of general purpose basic research, while other agencies undertake basic research related to their missions. In the past, the Foundation has awarded grants, based on proposals from research scientists, for projects which involve fundamental studies leading to new discoveries in aeronautics and space science. Under the stimulus of Federal support for space exploration and research, a larger number of proposals in these fields will be received by the Foundation. It is anticipated that the Foundation will be able to support an increasing number of such proposals in the future through research grants, chiefly to university scientists and engineers.

At the same time, NASA will support basic research more directly related to its own programs. NASA will be responsible also for scheduling rocket and satellite flights and packaging, recovery, and data receptions, working directly with the scientists and organizations concerned. Basic research support by the two agencies will be mutually complementary, and together they will assist in raising the level of understanding about basic phenomena in outer space.

National Academy of Sciences Space Science Board.—In cooperation with NASA, the National Science Foundation has undertaken the support of a committee of the National Academy of Sciences Research Council. This Space Science Board was established to study immediate problems, long-range problems, and the international aspects of both. The Board is an advisory and coordinating body, not an operating agency.

FEDERAL SPACE PROGRAMS

Civilian-oriented

Several Federal agencies other than NASA conduct research and development pertinent to the U.S. aeronautical and space program. Chief among these are: The Atomic Energy Commission, the National Science Foundation, the U.S. Weather Bureau, the U.S. Coast and Geodetic Survey, and the National Bureau of Standards of the Department of Commerce, and the Astrophysical Observatory of the Smithsonian Institution. The National Academy of Sciences, with support from the NSF, directed the U.S. part of the IGY program. Agency contributions during 1958 ranged from basic research in analyzing meteorological conditions and electromagnetic and gravity fields, to helping design and test many of the thousands of components needed for satellites and probes. In addition, some of these agencies were active in work supporting ground-based facilities for launching, tracking, and telemetering.

NASA 1.5 million-pound-thrust booster.—On December 17, NASA selected a contractor to design and develop a single-chamber rocket engine in the 1 to 1.5 million pound thrust class. Preliminary studies were begun on this program in 1957 by the Air Force. In June 1958 the Air Force, with ARPA approval, entered upon a preliminary design contract with an industrial source. NASA initiated the final design and development competition 3 weeks after being given responsibility for developing the high-thrust engine.

The engine is a booster rocket of 1 million pound nominal thrust, capable of being developed to 1.5 million pound thrust. It will use liquid oxygen and hydrocarbon propellants but could be adapted for other fuels. Special attention will be focused on methods of simplifying directional thrust control and of pressurizing propellant tanks.

On completion, the program will provide a booster of great size for payloads and experiments weighing several tons. The booster will eventually be used to propel manned satellites and spacecraft. It will also be clustered for larger payloads.

Manned satellites—Project Mercury.—One of the major, high-priority efforts under NASA management, with the advice and cooperation of ARPA, is Project Mercury, the manned satellite program. In November 1958, NASA invited 38 missile and aviation manufacturers to Langley Research Center to discuss preliminary specifications for a capsule suitable for use in manned space flight. Twelve companies bid on the project. NASA awarded a contract early in 1959. By the end of 1958, some 200 NASA scientists and engineers, including assigned military personnel, were engaged in Project Mercury work.

Project Mercury has a threefold objective: (1) to study man's capabilities for space flight, (2) to place a manned satellite in orbit around the Earth, and (3) to recover the pilot safely.

The capsule, as presently conceived, will be conical, about 7 feet in diameter at the base and 10 feet high. The pilot will lie in a couch-like frame, his back supported against the intense gravity stresses of takeoff and reentry. The base of the capsule will be mounted on an Atlas rocket. A suitable shield will protect him from the great, friction-induced heat of atmospheric reentry.

The satellite capsule will be launched into a circular orbit 100 to 150 miles above the surface of the Earth at a speed of 18,000 m.p.h. During the landing or recovery phase, retro-rockets attached to the capsule will fire, slowing it enough to drop out of orbit. The earth's atmospheric blanket will brake the capsule even more. Finally, parachutes will lower it to a landing. The capsule will be provided with escape mechanisms for use in case of emergency.

Careful preparation will precede any U.S. attempt to launch a manned satellite—a period of selecting and training personnel and testing the vehicle. Until U.S. scientists are convinced that they can send a man into space with a high degree of safety, the attempt will not be made.

Nuclear energy applications.—The Atomic Energy Commission has long-range programs for developing nuclear reactors for application in spacecraft. Under development also are small, lightweight nuclear powerplants to provide electricity over long periods for satellite instrumentation and other space applications—Project SNAP (System for Nuclear Auxiliary Power). In addition to power from reactors, conversion of nuclear energy into electricity is being sought—for example, the recently demonstrated SNAP-III device which produces electricity by means of solid-state converters from the energy released by the radioactive decay of polonium or other radioisotopes. SNAP-III has no moving parts, is extremely light, and has a long, useful life.

Work on Project Rover, a joint AEC-NASA endeavor to deveolp nuclear rockets, is centered at the Commission's Los Alamos, N. Mex., Scientific Laboratory and at its Nevada Test Site where high-temperature experimental reactors will be operated in ground tests only. During the past year the major effort was directed toward designing, developing, and fabricating the initial experimental reactor, christened "Kiwi-A," after the flightless New Zealand bird. This experimental device is now at the Nevada Test Site undergoing extensive checkout prior to operation in the spring of 1959.

Steppingstone to space—The X-15.—Latest in a series of advanced research vehicles for extremely high-altitude, high-speed experiments is the X-15 rocket-powered research aircraft. A joint undertaking of the Air Force, Navy, and NASA, the X-15 is expected to fly at speeds of more than 3,600 m.p.h. and possibly to reach altitudes of about 100 miles. It had its factory rollout in October 1958. Preliminary flight tests are scheduled for early 1959 at Edwards Air Force Base, Edwards, Calif. Later the X-15 will be carried aloft by a B-52 bomber which will drop-launch it for a steep power climb toward the fringes of space, after which it will take a long glide back to earth.

Through flights of the X-15, NASA will investigate: (1) severe aerodynamic heating caused by air friction at hypersonic speeds; (2) airplane stability and new types of aerodynamic control surfaces to keep the airplane flying on course at these great speeds; (3) rocket reaction control systems when the airplane is too high for aerodynamic forces to be sufficient; (4) pilot reaction to flight during short periods of weightlessness; and (5) many of the exit, reentry, and landing problems that spacecraft will encounter. Results of flights by the X-15, a transition between aircraft and spacecraft, will have important bearing on manned space vehicle projects.

Planning for research activities

During 1958, planning for investigations of the near areas of space broadened and gained momentum. These investigations will include high-altitude soundings, Earth satellites, and probes. For convenience, the research program in the physical sciences has been divided into atmospheres, ionospheres, energetic particles, electric and magnetic fields, gravitational fields, and astronomy.

Atmospheres.—This program includes an intensive investigation of the structure and composition of the Earth's atmosphere, using sounding rockets and satellites. Particular emphasis will be placed on obtaining and understanding daily, geographic, and seasonal variations, and their relationships between surface meteorology and the structure and dynamics of the upper atmosphere.

Ionospheres.—Here the object is to obtain electron density profiles at altitudes above the F–2 region (about 180 miles), using both sounding rockets and deep space probes. Latitude and time variations of electron density will be obtained by use of the polar-orbiting satellite beacon. The top-side sounding technique will be used in satellites. Very low frequency propagation measurements will be made in polar-orbiting satellites. Ion spectrum studies will be extended to the low mass numbers and higher altitudes by means of mass spectro-meters in both space probes and satellites. Direct measurements using antenna probes, ion probes, and electric field meters will be made in rockets and satellites to define in detail ionospheric structure and to study interactions between the ionosphere and space vehicles.

Energetic particles.—In the energetic particles progarm, the interactions of high energy particles with the Earth's atmosphere and field will be studies intensively, and the types and energy of such particles and their special distribution will be measured. Specifically planned are measurements of: (1) cosmic ray intensity in interplanetary space; (2) time and latitude cosmic ray intensity variations; (3) composition and spatial extent of the Great Radiation Belt; (4) the cosmic ray energy and charge spectrums; and (5) the nature of the particles producing auroras.

Electric and magnetic fields.—The program includes: (1) satellite investigations with proton magnetometers to study ring currents above the ionosphere and their relations to magnetic storms; (2) numerous sounding rocket experiments to investigate ionospheric currents; and (3) the use of magnetometers in space probes to observe electric currents and the form of the Earth's magnetic field at great distances, and to investigate whether the Moon has a magnetic field.

Gravitational fields.—In this program, a carefully instrumented satellite will be launched into a very high orbit to obtain precise geodetic data over a long period of time. In addition, a highly accurate clock in a satellite will be launched into orbit to test the general theory of relativity.

Astronomy.—The program will continue and be expanded. The survey of nebulosities in the far ultraviolet—a phenomenon discovered during the IGY—will be extended to the southern sky by means of rockets. Particular emphasis will be placed on using scanning satellites and rockets to observe the previously unexplored infrared and high-energy gamma ray spectral regions. Such studies will lay the groundwork for the satellite observatory program. Solar ultraviolet and X-ray spectra will continue to be investigated, including long-term variations, line profiles, distribution across the disk of the Sun, and the spectrum of the coronal X-ray flux. Deep space probes will be used to determine the nature and extent of the solar nebula and the interplanetary medium. A scanning satellite will be undertaken at an early date to map the emission of the high atmosphere which derives from charged-particle interactions and photochemical reactions.

Through these activities NASA is expanding the scientific investigations required to provide better understanding of the total environment in which man and Earth exist. Many investigations must be made repeatedly to obtain a continuous picture of the space environment. For example, radiation and micromicrometeor distribution must be measured again and again to chart their extent and to anticipate cycles of intensity and density, respectively.

The NASA program will include launchings of some 40 sounding rockets and their scientific payloads during 1959. Twelve complete satellite systems on order—some for 1959 launchings—will employ Jupiter, Thor-Able, and Atlas systems.

Defense-oriented

The military space program, administered by ARPA, includes a number of classified projects—for example, very early warning network. Among major unclassified military space activities that ARPA directed during 1958 were:

The Discoverer.—This project involves a series of vehicle launchings, chiefly from the Pacific Missile Range. Its purpose is further to develop new systems and techniques for production and operation of military space vehicles. The first launchings will be primarily to test the Discoverer vehicle and its subsystems, including propulsion and guidance. Later vehicles in the series will carry biomedical experiments to seek data on environmental conditions useful to Project Mercury.

Navigation satellites.—The purpose of this project is to institute a precise, all-weather system for determining sea or air position anywhere on the globe. The navigation satellite will be valuable to aircraft, surface vessels, and submarines. The project passed from the planning to the active stage in September 1958. Several satellite tests under this program are planned for the first 6 months of 1959. The first will be a 150-pound, battery-powered package, expected to stay aloft about 3 months. Later versions will be larger and longer lived.

Communications satellites.—The first test of the concept was the instrumented Atlas rocket placed in orbit on December 18, 1958. Present military requirements for rapid, accurate, and secure communications demand minimum antenna and transmitting equipment, least possible interference from daily changes in solar conditions, and freedom from jamming. Several experimental communications satellites will be launched in the spring and summer of 1959. In 1960 or 1961, so-called fixed satellites are planned. These devices will maintain a fixed position over a given point, revolving at the same speed as terrestrial rotation, at a distance of 26,000 miles from the center of the Earth. Three of these satellites could relay radio, television, and teletype messages continuously.

1.5 million pound clustered booster.—Work on this giant propulsion unit began August 15, 1958. Its purpose is to lift far greater payloads into orbit than so far have been possible. To form the booster, existing rocket engines and fuel tanks will be assembled in a cluster arrangement. By the end of 1959, present schedules call for ground-test firing of the cluster. Four booster test flights were ordered as part of the project.

High-energy upper stage.—In September 1958, ARPA began developing a high-energy liquid propellant engine for the upper stage of space vehicles powered by ICBM rockets. By the end of the year, contracts had been let to major industries in the rocket propulsion field to develop the upper stage and the engine. The upper stage in conjunction with existing boosters should be able to place multiton payloads in orbit. Direction of this project goes to NASA on July 1, 1959. Flight tests are scheduled for late 1960 or early 1961.

Meteorological satellite.—Reliable weather information is needed for military operations and for civilian activities too numerous to mention. The meteorological satellite project is seeking to fill gaps in present weather station networks by placing in orbit instrumented packages that can transmit rapidly over a large portion of the Earth's surface. They will be instrumented to detect and report cloud cover and temperature by infrared radiation and other means. Systems responsibility has been assigned to the Ballistic Missiles Division of the Air Force and responsibility for the payload to the Army Signal Corps. Instruments and data analysis has been assigned to the Air Force Cambridge Research Center, Cambridge, Mass.

Four meteorological satellites are scheduled for delivery in 1959. The meteorological satellite program is scheduled for transfer from ARPA to NASA July 1, 1959, and a launching is planned for fall or early winter. Six more packages will be used in laboratory and other environmental tests. NASA and the U.S. Weather Bureau are already taking part in the program.

Tracking.—In May 1958, the Army and Navy began developing a minitrack—DOPLOC (Doppler) fence across the Southern United States to establish a system for detecting nonradiating satellites. The network should begin operating experimentally in January 1959. A computing and filtering center is being developed at the Air Force's Cambridge Research Center. ARPA is coordinating this entire tracking effort with other Government programs to avoid duplicating major activities.

INTERNATIONAL ACTIVITIES

The International Geophysical Year

The year 1958 comprised the last two-thirds of the most intensive worldwide program of scientific investigations of the planet Earth and its environment ever undertaken. United States activities contributed heavily to the success of this first International Geophysical Year, which opened July 1, 1957, and came to an official close, December 31, 1958. IGY satellite and probe launchings by the United States were summarized early in this report. Many other IGY projects carried out by this country added to the fund of knowledge about the Earth and its cosmic environment.

Among participants in IGY space and astronautics investigations were various branches of the Armed Forces, NASA, the National Academy of Sciences, the U.S. Weather Bureau of the Department of Commerce, and the Astrophysical Observatory of the Smithsonian Institution, Cambridge, Mass.

Tracking activities.—During the IGY, U.S. scientists tracked U.S. and Russian satellites with a global network of optical and radio telemetry receiving stations. In addition, hundreds of volunteer Moon-watch teams contributed to the visual tracking phase.

A high degree of international cooperation marked the satellite tracking program; the same teamwork prevailed in the lunar and space probe tracking activities.

The Smithsonian Astrophysical Observatory at Cambridge, Mass., supervised the Moon-watch teams as well as a network of 12 optical tracking stations employing tracking cameras designed for the U.S. IGY program.

The U.S. Naval Research Laboratory—with the cooperation of the other services and other countries—established a "fence" of minitrack telemetry receiving stations stretching from the east coast of the United States down through the Caribbean and South America. Among the stations tied in with this network were installations in the Union of South Africa and Australia.

Contributing to the tracking of lunar and space probes were the giant University of Manchester radio telescope at Jodrell Bank, England, the Goldstone Tracking Facility (operated by the NASA-California Institute of Technology Jet Propulsion Laboratory) at Camp Irwin, Calif., and the Millstone Mountain, N.H., long-range radar developed for the Air Force by the Lincoln Laboratory of the Massachusetts Institute of Technology.

IGY findings.—Much highly significant knowledge emerged from the IGY, including—

Discovery of the Great Radiation Belt.

Determination of densities and pressures of high atmosphere to several hundred miles, and discovery that these quantities vary by as much as a factor of 10 with geographic position, time of day, and season of the year.

Upper atmosphere winds above the Arctic are extremely strong and from the west in winter, and relatively weak and from the east in summer.

Blackouts of radio communication in the polar regions are caused by an intensification at about 45 miles altitude of ionization produced by hard X-rays, emitted by the Sun during high solar activity such as flares.

Verification that auroral displays contain electrons and ions.

Identification of the ions in the ionosphere from 60 to several hundred miles, and proof that the principal ion in the highest part of the ionosphere is atomic oxygen.

Discovery that the sky, as seen from above the atmosphere, contains numerous sources of ultra-violet light which appear as diffused nebulosities.

Proof that the cosmic ray flux from outer space is markedly decreased in intensity at the time of sunspot maximum, indicating the existence of magnetic fields in interplanetary space.

Cospar.—Although the IGY has ended, important followup work will continue. In October 1958, the International Council of Scientific Unions met in Washington, D.C., and approved establishment of a Committee on Space Research (Cospar) which will carry on scientific cooperation in the spirit of the IGY.

The purpose of Cospar is to further, on an international scale, the progress of all types of scientific investigation carried out with the use of rockets or rocket-propelled vehicles. Cospar will be concerned with basic research and will not normally deal with such technological problems as propulsion, rocket construction, guidance and control.

Disarmament aspects.—For more than 2 years, the United States has been working through the State Department and the machinery of the United Nations toward the ideal of establishing space with its wealth of benefits as a peaceful domain for all mankind.

As early as January 14, 1957, the United States proposed in the United Nations the first study to lay groundwork for international agreements to assure that outer space will be used only for peaceful purposes. Later in the year, during the London Disarmament Conference, the United States joined Canada, France, and the United Kingdom in advocating a second study leading to an inspection system that would insure that activities in space will be solely for peaceful scientific purposes.

Henry Cabot Lodge, U.S. Ambassador to the United Nations, stated in October 1957 that this country was willing to enter into technical talks on the matter without waiting for other disarmament negotiations to be completed.

Correspondence between the President and then-Soviet Chairman Bulganin in 1958 indicated that space aspects of disarmament negotiations would prove both delicate and complicated. This Government has concluded, therefore, that the United States should seek international agreement on developing cooperative programs for the peaceful uses of outer space separate from its continuing efforts to bring about agreement that outer space will be used only for peaceful purposes.

Peaceful activities.—Because peaceful cooperation for activities in space is vital, the United States is considering approaches through: (1) international organizations (governmental and private), (2) bilateral and multilateral agreements, government-to-government, or (3) unilateral proposals or invitations for foreign organizations or individuals to take part in U.S.-sponsored space activities. Obviously, varying types of space undertakings require different methods of international cooperation.

During the past year, the United States proposed that the United Nations concern itself with problems and planning related to use of outer space for peaceful purposes. On November 13, the United States and 19 other nations jointly introduced a resolution in Committee I, U.N. General Assembly, which called for creation of an ad hoc committee to—

> Make an inventory of the activities and resources of the United Nations, its specialized agencies, and other international bodies relating to peaceful uses of outer space.
>
> Determine the area of international cooperation and programs in the peaceful uses of outer space that could appropriately be undertaken under U.N. auspices.
>
> Consider the form of organization in the United Nations that would serve best to bring about full international cooperation in this field.
>
> Survey the nature of the legal problems that may arise in carry out activities in space.

Attempting to reach unanimous agreement on the resolution, the United States and its cosponsors introduced an amended resolution, November 21, 1958, instructing the Committee to consider certain proposals contained in a Soviet resolution. Ambassador Lodge discussed the resolution thus:

> In deciding what the United Nations should do, it will be necessary to consider the role and activities of the specialized agencies, and of international scientific bodies before coming to firm conclusions on this subject. For example, there convened in London only a few days ago the Committee on Space Research (Cospar) organized by the International Council of Scientific Unions (ICSU), in which both American and Soviet scientists participate.

The Soviet bloc voted against the resolution because it opposed the membership of the Committee. The Soviet representative at the United Nations later stated that the U.S.S.R. will not work with ad hoc Committee. Although the inventory requested by the resolution and the studies called for can be conducted without Soviet participation, the United States continues to hope that the Soviet will participate. The General Assembly approved the resolution on December 13, by a vote of 53 in favor, 7 opposed, and 19 abstentions.

RESEARCH IN SUPPORT OF AERONAUTICS AND SPACE

The year 1958 saw a blending of aeronautics and space research in which a number of agencies are engaged. When NACA was absorbed by NASA in October, about half of its research was applicable to the problems of space technology. Research applicable to space will continue to expand at an accelerating pace but the advent of the space age does not mean that the speed, safety, and efficiency of the airplane will become less important. NASA is continuing its basic and applied research in support of atmospheric flight, in cooperation with the Department of Defense, the National Science Foundation, the U.S. Weather Bureau, the National Bureau of Standards, and other agencies.

The division between aeronautics and space research is, at best, arbitrary. The supersonic airplane, for example, uses atmospheric air for combustion; the hypersonic rocket carries its own oxidizer—yet jets and rockets have similar fundamental problems of aerodynamics, combustion, and materials. The stratosphere, where jet planes operate, merges imperceptibly into "space." Results of aeronautical research are often applicable to space craft, and vice versa.

The research considered here under general headings has been going forward primarily in Government laboratories. A research program in the laboratories of industrial, educational and research institutions is now underway.

Aerodynamics and flight mechanics

A major research effort in 1958 was devoted, as in previous years, to the aerodynamic problems attendant upon high-speed flight by aircraft and rockets through the atmosphere. These problems—especially aerodynamic heating caused by friction—become acute when a vehicle slams back into the Earth's atmospheric envelope after a trip through space. Particular emphasis has been placed upon heat protection, control, and safe landing of manned space vehicles.

Reentry.—Landing problems have occupied a large share of research attention throughout the history of flight. However, they are in-significant compared to the complications involved in successful recovery or landing of a space craft.

For a manned satellite or space vehicle, the landing approach begins in airless space where the pilot, human or automatic, alines the vehicle to begin atmosphere reentry. Reaction controls or gyroscopic devices will be used to accomplish this task.

In a vehicle that depends upon aerodynamic lift for controlled flight in the atmosphere, a transition is made from space controls to aerodynamic controls as it enters the atmosphere. Then effective command of the vehicle must be maintained during a very wide range of accelerations and rapid changes in air density and dynamic pressure while speed is reduced from 18,000 miles per hour or more. to a safe landing speed.

In consequence, a whole new family of piloting and control problems appears and the cost and complexity of flight operations multiply.

A number of reentry methods for manned vehicles are being explored. One is the ballistic reentry that does not employ aerodynamic lift for flight control through the atmosphere. This calls for a shallow reentry initiated from a carefully established orbit, after which the vehicle would follow a stable but essentially uncontrolled flight path to a point near the Earth where a parachute could be used for landings. Aerodynamic configuration research in this case is directed toward body shapes which will absorb the least amount of heat and also remain stable through the entire range of speeds encountered.

Disadvantages of the ballistic reentry vehicle include the relatively high decelerations to which the occupant would be subjected and the difficulty of controlling the precise landing point.

A second way to keep surface temperatures within tolerable limits is to use aerodynamic lift during reentry. In this way the vehicle remains longer at higher altitudes and the heat is generated more gradually. Use of lift for reentry permits lower decelerations, a most important consideration for the pilot.

Lift, too, has disadvantages. To obtain it, the blunt, high-drag forms known to permit successful ballistic reentry must be altered. As greater lift is required, the vehicle becomes more flattened and the amount of blunting that can be tolerated gradually diminishes.

Studies have revealed a number of possible variations on these two methods of reentry flight and further possibilities will undoubtedly come to light. These findings have been accompanied by steady progress in analytical and experimental research on a large number of detailed questions concerning flow phenomena and heating at extreme speeds, aerodynamic forces, vehicle stability, and means of flight path control. Work has also progressed in the study of orbits and interplanetary trajectories and analytical methods have been worked out that simplify the calculation of these paths. Analytical studies have also been made on the initiation of atmosphere reentry from orbit by use of braking rockets.

High speed and vertical takeoff and landing aircraft.—Aeronautics research has concentrated upon supersonic and hypersonic aircraft at one end of the speed spectrum, and VTOL (vertical takeoff and landing) and STOL (short takeoff and landing) aircraft at the other. Continuing study of wings, bodies, and wing-body combinations has led to the development of efficient configurations for advanced supersonic military airplanes and for the high-speed, subsonic jet transports which have just recently come into general use on the civil airlines.

Research in VTOL and STOL aircraft has been concerned with several propulsion types, such as rotors, propellers, ducted fans, turbojets, and annular jets. With each type, different principles for achieving the required lift at zero or low forward speeds have been investigated. Dual propulsion methods, for example, are under study as well as systems whereby the thrust is redirected in takeoff and landing to provide additional lift either by tilting the entire thrust unit or by deflecting the thrust from a fixed unit.

Attention is being given to the critical problem of stabilizing and controlling such aircraft in all conditions of flight, including hovering, transition from hovering to level flight (and vice versa), steep climb, and landing approach. The turbojet thrust deflection airplane, the deflected propeller slipstream airplane, and the tilting propeller-wing airplane are but a few examples of this type of aircraft which have the lift advantages of helicopters but greater flying speed.

Wind-tunnel and flight testing of these airplanes has generally been a cooperative effort among the NASA, industry, and the military services.

Flight simulators.—With the advent of vehicles that fly at great speed, under delicate aerodynamic conditions, an increasing need is found for flight simulators. Testing of high-performance aircraft in actual flight is expensive and paradoxically limits the scope of conditions that can be studied without danger to the pilot or the craft. Simulators not only save money and eliminate the danger, they also serve to train pilots in new types which are radically different from the machines they have been flying. An example is the X–15. In a simulator, pilots for the X–15 had experienced most of the conditions expected in actual flight before the craft was even rolled out for ground tests.

Powerplants

Research and development on high-energy fuels for airbreathing (jet) engines continues to be a high-priority program in which NASA and other Government agencies are cooperating. Typical of the program is the quest for a satisfactory burner to use liquid compounds of the element boron. Boron burns at elevated temperatures but also with high heating value per unit of weight. The higher the heating value per pound of jet fuel, the greater is the range of the craft using it.

Hydrocarbon fuels can deliver on the order of 18,500 B.t.u. (British thermal units) of heat per pound. Hydrogen as fuel is capable of 51,000 B.t.u. but containers for such a low-density fuel appear to be too bulky to be practicable. Research is aiming for boron-containing liquid fuel mixtures approaching 27,000 B.t.u. per pound. Substantial progress has been made with experimental burners for short periods with a boron-containing fuel delivering some 25,000 B.t.u. per pound.

Until recently, a factor severely limiting utilization of boron fuels has been that boron-oxide deposits encrust the afterburner, thus rapidly lowering efficiency. During 1958, an afterburner of new design was tested. It was found appreciably freer of the boron-oxide deposit problem than were earlier versions. Although much research and development in this program is classified, it can be stated that boron now appears feasible as a high-energy jet fuel.

Advanced jet aircraft.—Propulsion research for jet aircraft in the mach 3 or mach 4 class (three or four times the speed of sound) is nearing completion. There is a large area—that of speeds above mach 4—about which research scientists need much more knowledge.

NASA is planning research to determine whether practical vehicles can be built capable of sustained velocities at mach 4 and above. One key to the success of these vehicles is associated with the engine performance. Engine problem areas in question are inlet size and configuration, combustion chambers, exhaust nozzles where gases exit at temperatures of 4,000° F. or more, and problems of cooling. Recent progress in associated fields has provided a good foundation upon which research into the possibilities of ultrafast supersonic aircraft can be based.

New rocket propulsion energy sources.—The goal of research to provide better rocket fuels is the same as that for high-energy fuels for aircraft—to produce the greatest possible propulsive energy from the least possible weight and volume of fuel.

Today's rocket engines depend on liquid and solid propellants, either separately or in combination for different stages of a booster. Limits to development of chemical propellants can be foreseen. Advanced research is therefore focusing on other possible energy sources and on engines to use them. Under investigation, as previously discussed, is use of a nuclear reactor with hydrogen as propellant. In such a device, hydrogen would be heated to very high temperatures by passing through the hot reactor.

Theoretically, major gains in nuclear engine performance are available. However, research problems associated with the fuel elements, reactor control, nozzle cooling, and vehicle shielding, while offering no insurmountable obstacles, will be costly and time-consuming to solve.

Nuclear aircraft, missiles, and spacecraft propulsion.—In addition to work noted earlier in this report, there is vital research and development in the field of nuclear propulsion for powerplants.

A joint AEC-Air Force project (Pluto) is developing a ramjet propulsion system for use within the Earth's atmosphere. Work is centered at the University of California's Radiation Laboratory at Livermore, with the support of private industry. Design and construction of the first experimental reactor—Tory-II—for this project started in 1958, and is progressing satisfactorily.

During 1958, initial test and some supporting facilities required for Rover, a project noted in an earlier section, and Project Pluto were completed at the AEC Los Alamos and Livermore installations, respectively. A zero-power reactor (one producing just enough nuclei to sustain a chain reaction) at the NASA Lewis Research Center, Cleveland, Ohio, was completed during the year. The NASA Plum Brook 60-megawatt reactor at Sandusky, Ohio, is expected to go into operation in 1959.

Two main approaches toward nuclear engines for aircraft are being developed by industrial contractors under AEC-Department of Defense programs.

In the direct-cycle system, air from a turbojet engine compressor is heated directly in a reactor core before passing through turbine and exhaust. In 1958, a number of core tests directed toward attaining higher reactor temperatures and power levels, were made at AEC's National Reactor Test Station in Idaho. Modified J-47 turbojet engines were used but future tests will be carried out with specially designed turbojets.

For the indirect-cycle system, air from a turbojet engine compressor is heated as it passes through a radiator system outside the reactor. The heat is carried to the radiator by a liquid metal coolant piped from the reactor. The immediate objective of the current program is to determine the technical feasibility of a high-temperature reactor having very high specific power. During the year encouraging improvements were made on advanced reactor coolants, structural materials, and fuel elements.

Construction of a flight engine test (FET) facility at AEC's National Reactor Test Station in Idaho was approximately 80 percent done by the year's end. FET will be used to test advanced flight prototype propulsion systems installed in full-scale aircraft or mock-ups.

Aircraft, rocket, and spacecraft loads and structures

This field of research is concerned with the design of the structure which provides the streamlined shapes and smooth exterior surfaces required by the aerodynamicist, and houses the propulsion and control systems, as well as the payload, human or otherwise. The goal is to provide a basis for developing sound structures of minimum weight. Further research in loads prediction, material selection and development, and structural arrangements is required.

Here, again, the problem of prime importance is aerodynamic heating. In every case, the aerodynamic means for controlling reentry heating dictates some internal provision for keeping the reentry vehicle cool or for dealing with the quantities of heat that must inescapably be absorbed.

The specific method or combination of methods will vary with the conditions of reentry, the shape of the vehicle, and the flight path it follows. In some cases the rate of heat absorption during reentry is the crucial factor; in others, lengths or exposure times become more important, and the total heat demands attention.

Several well-tried cooling systems and some less familiar are receiving attention. One system uses a cooling fluid pumped through passages next to the skin of the vehicle to absorb and carry away incoming heat.

Transpiration cooling may be adaptable to returning space vehicles. A coolant liquid pumped through a porous skin absorbs heat and then flows over the vehicle, insulating the surface from the hot layer of adjacent air.

A third method is called ablation cooling. The surface of the vehicle is coated with a substance that vaporizes progressively during heating. The vaporizing process absorbs heat and the gases produced insulate the skin over which they flow. The ablating material will eventually be consumed, but a half-inch coating of some materials could protect a rocket glider through a 20-minute hypersonic flight.

Radiation provides valuable cooling. A moderate increase in surface temperatures relative to the surroundings will result in more heat being radiated away from a vehicle. If surface materials can withstand high enough temperatures, radiation cooling will be sufficient. Unfortunately, the hot skin radiates into the vehicle as well as out from it. Thus, additional internal protection must be provided for crew and equipment.

Although heat sinks—materials that absorb and store heat—will absorb and store reentry heat, great quantities of such materials are required to safeguard a vehicle for long periods.

Conduction can be useful in combination with a heat sink. A good conductor will carry the heat from the hottest surface regions of a vehicle to cooler areas where it can be stored. Once again, weight would be a severe problem with conduction materials now available.

The tendency of aircraft structures to "flutter" in the supersonic-hypersonic speed range plagues designers. Flutter is produced by interaction of structural qualities—flexibility or stiffness—with weight distribution and aerodynamic forces. These relationships are so complex that theoretical predictions of flutter seldom are accurate enough to solve the problems; experimental corrections are usually necessary. Studies of this kind with new aircraft designs are therefore continuing, as are analyses of load factors on aircraft in rough air.

Operating problems

Crash fire prevention, noise reduction, ditching aids, crash survival, and landing or takeoff procedures are among the practical questions that arise in aircraft operations. Often they overlap the problems of aerodynamics, propulsion, and structural design. Here, only a few projects involving passenger safety and comfort are mentioned.

Investigation has shown that a frequent cause of crash fires in turbojet aircraft has been fuel spilled during the crash, and sucked into the engine with the intake air. Flames escaping from the tailpipe then would ignite the spilled fuel on the ground. It was found that fires of this kind could be prevented by a water-dousing system to quench the combustor flames and to cool the hot metal in the engine.

Recent studies of the turboprop engine have demonstrated an effective method to smother the combustor flames at the time of a crash. Manufacturers are now applying this technique to some aircraft.

For several years, jet noise has been studied intensively at NASA's Lewis and Langley Research Centers.

Two types of noise suppressor that attack the problem at its source—the jet exhaust—have evolved from this program, and now are in use on the new transports. These are the corrugated multiple-tube nozzle and the shrouded nozzle.

Both have the disadvantage of adding some weight to the aircraft, reducing engine performance slightly, and increasing drag. NASA is continuing to test various configurations in wind tunnels to improve the aerodynamic qualities.

Supersonic jets have introduced a new noise problem into routine flight operations—the sonic boom, from shock waves following the craft traveling downward through the air. From data collected by NASA, pilots are taught how to hold the intensity of the boom to a minimum.

CONCLUSION

During 1958 a large segment of the Nation's scientists, engineers, and production experts were drawn together and given direction. Against this background the country carried out a series of space experiments that yielded invaluable data to the world's store of scientific knowledge and established a firm foundation from which to launch the space activities of coming months.

There were a number of failures during the year and we promptly announced them. A beginning has been made of which we may well be proud. We are, however, only just over the threshold. Much research, reevaluation, and work lies ahead for us. The United States is aware of the magnitude of the challenge and aware that it must be fully met.

O